Nuclear INFORMATION

Greater St. Louis Citizens' COMMITTEE FOR NUCLEAR INFORMATION

VOL. II No. 4 ST. LOUIS, MISSOURI DECEMBER, 1959

RADIOACTIVE WASTES - AN UNSOLVED PROBLEM

A great deal has been said about the vast amounts of energy that nuclear power can provide for the world's economy. But until recently we have heard little about the industry's big housekeeping problem – the disposal of the radioactive wastes that atomic plants produce. Now that this matter has been examined at hearings last August of the Joint Congressional Committee on Atomic Energy, the picture is clearer. The problem of disposing of such wastes without harming people or the plants and animals they eat is a severe one, and no adequate solution is in sight yet.

Two kinds of large-scale nuclear industrial activities are in operation now: mills for refining uranium, and reactors designed to convert uranium into plutonium, which is used in bombs, or to produce power from the splitting of uranium. Both types of operations produce numerous radioactive waste substances in large quantities. These by-products pose a new problem in public safety, for some of the substances, unlike any wastes ever produced before the atomic era, retain their dangerous radioactivity for decades or even centuries. Thus their continued accumulation could in time raise the radioactivity of the earth to a level that would threaten the well-being of living things.

In this issue, *Nuclear Information* explores the general problem and takes up a specific case that shows what is already happening. In the columns below we discuss first the kinds and sources and amounts of radioactive wastes, how they are being handled now, and what might be done about the larger amounts that will be produced in the future. The second article reports on the situation in the Columbia River basin in Washington, where the great Hanford reactor has been in operation since World War II. It appears that the Hanford radioactive wastes have put a serious limit on the amount of local fish and ducks and vegetables that can be safely eaten.

Disposal of Radioactive Wastes

To see how important the control of radioactive waste is going to be in the future, all we need are a few numbers. If nuclear power grows in the United States at the rate now predicted, we shall have accumulated 6 billion curies (a curie is the amount of radioactivity given off by 1/28 of an ounce of radium) of strontium-90 by the end of this century.[1] That's 30 times as much strontium-90 as would be released by the nuclear war envisioned by the May, 1959 Congressional hearings on nuclear war. Assuming that the maximum permissible concentration(MPC) of strontium-90 in drinking water is 80 micromicrocuries per liter (about a quart), 6 billion curies is enough to contaminate 16 million cubic miles of water to the level of the MPC. Sixteen million cubic miles is more than all the fresh water in the world. The significance of the expected amount of strontium-90 in radioactive wastes in the year 2000 – 6 billion curies – can be judged from the fact that the absorption of less than one curie of strontium-90 is lethal to a human being.

Other radioactive elements would accumulate too. Here are some estimates for the year 2000:

Cesium-137	5,300 million curies
Prometheum-147' . . .	6,070 million curies
Cerium-144	10,100 million curies
Americium-241.	1.1 million curies
Curium-242	3.3 million curies

Although all of these retain their radioactivity for a long time, americium-241 is especially important because it takes 510 years to lose half of its initial radioactivity.

One can get some idea of the capacity of nuclear reactors for contributing to the radioactivity of the world by looking into the quantities of useful radioactive isotopes that have already been produced for

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What's Happening to the Columbia River?

Since the early 1950's, the dumping of uranium mill wastes in some of our western rivers has been causing concern. Even a decade ago, several Colorado streams below uranium mills were found to have as much as 86 micromicrocuries of radium per liter – more than twice the maximum permissible concentration in drinking water. In 1956 the U.S. Public Health Service reported that the tap water of one small western community that used the local river as a water source ". . . had slightly more than the allowable dissolved radium content for general population exposure." (Ref. 2, p. 1050) In recent months the Public Health Service has taken legal action to halt radioactive contamination from uranium mills.

The shape of things to come is most clearly foreshadowed by conditions in the Columbia River basin, seat of the nation's largest atomic installation, the great Hanford Works. This installation, which covers 567 square miles along the river in the western part of the state of Washington, operates several big reactors in which uranium is irradiated to produce plutonium – a prime ingredient of nuclear bombs.

The River Cools the Reactors

The reactors liberate radioactive material into the river water that is used to cool them. Although the water is not normally in contact with the fuel in the reactor, it is nevertheless bombarded by neutrons that convert some of the minerals dissolved in the water into radioactive substances. Moreover, a reactor tube occasionally bursts, releasing its load of radioactive material into the water. On leaving the reactor the water is held in retaining basins for 1 to 3 hours, and then is returned to the river. Since many of the isotopes created by the

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Disposal of Radioactive Wastes

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industry, medicine, and research. Between August, 1946, and November, 1958, the Oak Ridge National Laboratory alone shipped 437 curies of radioactive materials to scientists and industries licensed by the AEC.[2] All the other national laboratories together shipped an equal quantity. Yet current reactor operations are only a fraction of what is expected for the year 2000, when nuclear reactors may be widely used for generating power.

Where the Waste Comes From

Reactors in use today are of two types. In one type the fuel is contained in solution within the reactor. In the other the fuel is jacketed in inert material. Poisoning and pressure in the latter type, however, make the fuel element ineffective after only 1 to 2 per cent of the fuel has been actually used. Because of the high cost of refined uranium, it is essential to recover the unfissioned fuel and use it again. It is this recovery process that causes the major part of the waste disposal problem. After one gram of uranium-235 has been consumed, recovery of the fuel remaining in the element leaves about a third of a gallon of radioactive waste. More than three months after the element has been removed from the reactor, one gallon of such waste will contain about 1500 curies.

The liquid wastes are treated according to their level of radioactivity. Low level wastes, with only a trace of activity, are discharged directly without decontamination. Intermediate level wastes, with activities up to 0.1 of a curie per liter,[2] are either diluted or partly decontaminated before being released into the earth or rivers. High level wastes, having activities up to thousands of curies per gallon, are stored in tanks. This is an effective solution for the present, but probably not for the future. Storing all the high level waste that nuclear power-generators will produce would require vast numbers of enormous tanks that would have to remain sound and leakproof for hundreds of years.[1]

What Happens in the Soil

At present it is the disposal of the intermediate level wastes that is causing the greatest concern. Such wastes are often discharged into shallow pits dug in the soil. As the water seeps down, much of the radioactive material is retained in the soil and thus prevented from accompanying the waste water into the underground water system. The difficulty is, as Dr. Wallace de Laguna of the Health Physics Division of Oak Ridge National Laboratory has pointed out, that ". . . it is not possible to determine accurately the pattern of movement of waste solution through the ground."[1]

Although 2 million dollars are now being spent annually on the control and monitoring of waste disposal,[2] it is by no means certain that this method of waste disposal will not eventually contaminate water supplies seriously. The problem is bound to become more pressing in the future as the output of radioactive waste rises. A committee of the National Academy of Sciences (N.A.S. Publication 519, April 1957, p.9) has recently come to the conclusion that the disposal of large volumes of low level wastes above the water table "is of limited application and probably involves unacceptable long-term risks."

The reactors already in operation discharge more than a billion and a half gallons of low and intermediate level wastes per year. The level of reactor operation anticipated by the end of this century would require the handling of many times that quantity.

The Problem Must Be Faced

The problem of waste disposal is crucial to the development of atomic energy industry. Although the experts are generally agreed that an extensive research program is required before the output of waste material from large-scale nuclear power production can be safely handled, not everyone is aware of how serious the matter is.

Dr. Abel Wolman of Johns Hopkins University, a member of the AEC Advisory Committee on Reactor Safeguards, recently stated that ". . . to many industrialists the problem of waste disposal appears to be non-existent. The reason for this happy state of affairs lies in the fact that under present procedures the Atomic Energy Commission holds itself responsible for the handling of these most difficult materials."[2] But as Dr. Wolman goes on to explain, "Progress in this field is unlikely to occur if the problems are not realistically confronted. . ." Just as the Public Health Service has recently taken over from the AEC the supervision of radioactivity in foods, it appears that some other independent agency will have to take over the matter of establishing criteria for safety in waste disposal.

What Could Be Done

Possible solutions to the waste disposal problem have been suggested by the National Academy of Sciences' Committee on Waste Disposal.[2] One possibility is to convert the waste to solid and mould it into blocks with an inert ceramic binder. The blocks could be stored in underground diggings, such as abandoned limestone mines. But this procedure is expensive, and requires high temperatures which vaporize the material and produce radioactive gases and aerosols that might be difficult to control.[1]

Another disposal method, which the Committee regards as the most promising, involves the construction of cavities in salt formations in which the liquid waste could be stored. Salt forms an impenetrable barrier to liquids when it is heated slightly. But the radioactive decay going on in the concentrated waste would build up high temperatures that might result in violent boiling. This drawback places a limit on the size of the salt cavities that might be used for storage.

The third possibility suggested by the Committee is storing the waste in very deep underground wells. Since water movement in porous formations deep underground is known to be very limited, it seems quite certain that waste stored in such formations would have no opportunity to mix with ground water near the earth's surface. But there are difficulties involved in this method too.[1]

Dump It in the Ocean?

Dumping radioactive waste into the ocean has been suggested frequently. The oceans are so enormous that 10 billion curies of strontium-90, uniformly distributed, would be only 1 per cent of the MPC for ocean water.[2] Since ocean waters do not mix very well, however, very large variations in concentration (as much as 1000-fold)

are to be expected. Furthermore, even when sea water is at 1 per cent of the MPC, fish living in it can accumulate enough radioactivity to make them dangerous as food. These facts rule out disposal of high level waste in the ocean.

Disposing of intermediate and low level wastes in the ocean does not seem to be a wholly safe procedure either. Sealing up the waste in heavy containers has been suggested, but it is quite possible that such containers could be accidentally broken or dredged up. In addition, the international legal aspects of contaminating the oceans with radioactivity are still to be explored. We really are not sure how ocean currents would distribute the material. We do not know very well how fishes and the plankton that some of them feed on would be affected by the radioactivity. At the recent Congressional hearings, a witness pointed out that we know so little about the behavior of one radioactive element, tantalum-182, that no one can decide how much is safe in sea water. Yet the new nuclear ship Savannah will produce radioactive waste that is mostly tantalum-182.

With sufficient manpower, time, and money, all these questions could be answered. The answers must be found. Otherwise, the unsolved problem of how to get rid of its waste may block the further development of the nuclear power industry.

Columbia River

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reactor decay within minutes, the delay cuts the radioactivity of the water to about half its original level.

But some radioactivity remains. When the Columbia River reaches the cities of Pasco and Kennewick, 50 miles downstream, the water still has 10 per cent of its original radioactivity. When it flows into the sea at Astoria, 350 miles from Hanford, the river still has more than the amount of radioactivity normally found in river water, according to the Public Health Service.

The question is, is the radioactivity of the Columbia River harmful?

The area around the Hanford plant, though isolated, is by no means devoid of people. About 35 miles downstream from the plant is the city of Richland, with a population of 25,000, and a few miles further on Pasco and Kennewick have a total of 27,000 people. The Columbia River basin is moreover a popular fishing and hunting area.

What the Hazards Are

Radioactivity from the Hanford operations can reach people in several different ways. (1) Columbia River water, made radioactive in cooling the reactors at Hanford, is the source of drinking water for Pasco and Kennewick. (2) Plants growing in and along the river accumulate radioactive elements that get into the fish and ducks that eat the plants. People eat the fish and ducks in turn. (3) River water is used to irrigate crop and pasture lands, so that water-borne radioactive isotopes find their way into vegetables and meat. (4) The exhaust stacks at Hanford release some radioactive waste into the air. This material gets into people by way of the air they breathe and the food they eat.

At the Congressional hearings on waste disposal, the manager of the Hanford plant concluded his testimony with the following statement:

> In brief summary, the actual exposure to persons in the environs of the Hanford plant is estimated to be between 3 per cent and 15 per cent of the currently accepted limits. For exceptional cases, where unusual amounts of local fish and leafy vegetables are eaten the exposure may reach as much as 40 – 60 per cent of the appropriate limits. (Ref. 2, p. 182)

Radioactivity in Vegetables

A somewhat different estimate of the hazard is reported by a group of Hanford radiation experts (J.W. Healy, B.V. Anderson, H.V. Clukey and J.K. Soldat) in a paper, "Radiation Exposure to People in the Environs of a Major Production Atomic Energy Plant," that they presented to the 2nd International Conference on the Peaceful Uses of Atomic Energy in Geneva in 1958.[3] This article calculates, for example, the effects of eating about 3½ pounds per week of green vegetables grown in the Hanford area. (In the U.S. the average amount of fresh vegetables eaten per person per week in 1953 was 2¾ pounds.) The calculations show that during 1957 the resultant radiation exposure to the digestive tract varied from month to month between a low of 7% of the radiation limit recommended for the population (September) and a high of 130% (June). The average radiation exposure from this source alone was half of the maximum permissible limit for the population. Even for people living about 40 miles from the plant, eating 3½ pounds of vegetables per week gave the digestive tract an average of 53% of the maximum permissible limit for the population.

Vegetables are only one of the sources of radioactivity in the Hanford area. Additional radiation is received from drinking water, breathing air, and eating local fish and ducks. When the effects of *all* the sources are added up, it turns our – according to the article presented at the Geneva conference – that for people living in the environs of the plant total exposure to the digestive tract amounts to 75% of the maximum permissible level. For bone, total exposure is 50% of the maximum permissible limit.

The Fish Are Radioactive Too

The situation relating to fish in the Columbia River is particularly interesting. One of the chief radioactive contaminants in the cooling water from the Hanford works is phosphorus-32. This becomes concentrated in the plants, and ultimately in the fish that feed on them and on plant-eating animals. Whitefish taken from the Columbia River may contain phosphorus-32 thousands of times more concentrated than in the water in which they live.

For these reasons Hanford biologists have kept a close watch on the radioactivity of whitefish and other

Nuclear Information is published 10 times a year by the Greater St. Louis Citizens' Committee for Nuclear Information. Address: Room 318, Museum of Science and Natural History, 2 Oak Knoll Park, St. Louis 5, Missouri. Phone: PA 5-7055.

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Subscription rate: Individual, $2 per year; Organization (6 copies per issue), $5 per year.

Columbia River fish. In 1957, D.G. Watson and J.J. Davis of the Hanford staff pointed out (Report No. HW-48523) that the Rocky Mountain whitefish is an important food and game fish which is being sought by an increasing number of anglers. On some days during the fall and winter, Watson and Davis state, ". . . as many as one hundred persons have been observed fishing in sections of the Columbia River immediately above and below the HAPO [Hanford] reservation." Between June of 1950 and the end of 1956, the Hanford biologists caught and analyzed 1500 whitefish. Their findings led them to this important conclusion:

> Human consumption of whitefish at the rate of 2.7 pounds per week from public fishing areas (near the Hanford plant) during the fall would produce the maximum permissible concentration of phosphorus-32.

Since wild duck caught near Hanford contain about as much phosphorus-32 as fish, eating 2.7 pounds of duck and fish combined would expose a person to the maximum permissible concentration of phosphorus-32. And since the flesh contains other radioactive materials, the allowable consumption would have to be reduced still further.

Is the Public Informed?

How much of this information is familiar to the people who fish and hunt in the Hanford area is not known. If the people are made aware of the hazard, they can reduce exposure by some fairly simple steps. For example, frying whitefish causes some of the activity to move from the flesh to the skin, which could then be discarded. Keeping the fish in a frozen or smoked state for about two months would also be advisable, because phosphorus-32 is a fast-decaying element that loses half of its activity in 14 days.

Other Rivers

The Hanford plant is probably the largest reactor in the country, but other smaller ones also affect the rivers that are near them. For example, at the Congressional hearings it was reported that the radioactivity of the Clinch River, in Tennessee, which receives some of the wastes from Oak Ridge, varied between 17 and 55 per cent of the maximum permissible concentration for drinking water.

Other rivers that may be affected are the Savannah, Ohio, and Mohawk. The radioactivity of the first two of these rivers appears to be quite low at present. However, the Mohawk River situation may become a problem.

The Knolls laboratory, which develops nuclear reactors for submarines and destroyers, releases radioactive waste into the Mohawk River. Since the city of Cohoes, downstream from the Knolls plant, uses Mohawk River water for drinking purposes, after the usual purification, the radioactivity of Cohoes tap water is surveyed regularly.

The Knolls "Health Physics Report" for Oct. - Dec. 1957, shows that of five analyses of tap water from Cohoes made in December 1957, four gave less than 40 micromicrocuries per liter (how much less is not known, because the relatively insensitive technique used will not detect less than 40 micromicrocuries of radiation per liter), but one analysis showed a value of 69 micromicrocuries per liter – almost equal to the maximum permissible concentration for strontium-90. According to the report, no activity was detected in the river at Cohoes when the contaminated tap water was found.

In sharp contrast to the uncertainties that plague the waste disposal situation is the fact that within the well-ordered nuclear plants, the safety record for accidental exposure of workers to radiation seems to be remarkably good. It would appear that we have learned how to protect ourselves from radiation – but only when we know exactly where it is. Once the radioactive material is permitted to escape to the vast and uncontrolled spaces where the rest of us live, it may turn up in hazardous forms in unexpected places.

REFERENCES

The reference numbers in this issue's articles relate to:

1. "What is Safe Waste Disposal," an article by Dr. Wallace de Laguna in the Jan. 1959, issue of the *Bulletin of the Atomic Scientists*, p. 35.
2. Hearings on Industrial Radioactive Waste Disposal before the Special Subcommittee on Radiation of the Congressional Joint Committee on Atomic Energy, Jan. 28 – Feb. 3, 1959. (These 4 volumes can be obtained from the Joint Committee or your Congressman.)
3. Proceedings of the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva, Sept. 1958. Vol. 18, Waste Treatment and Environmental Aspects of Atomic Energy.

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